STATEMENT; Comments on the next 50 years (based on non-power civilian applications) based on President Eisenhower's vision of 1953.

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1. President Eisenhower's vision:

In his historic address to the United Nations of 8 December 1953, President Eisenhower sought to "hasten the day when the fear of the atom will begin to disappear from the minds of people and governments" and expressed confidence that the "greatest of destructive forces can be developed into a great boon, for the development of all mankind". He proposed an international atomic energy agency under the aegis of the United Nations undertaking a number of rolls associated with the control, administration and safeguarding of fissionable material. As vitally important as these rolls are, President Eisenhower went on to say "The more important responsibility of this atomic energy agency would be to devise methods whereby this fissionable material would be allocated to serve the peaceful pursuits of mankind. Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine and other peaceful activities. A special purpose would be to provide abundant electrical energy in the power-starved areas of the world."

President Eisenhower's vision for the civilian applications of nuclear technology over the past 50 years has been realised to a greater extent than could be realistically predicted at the time. Ignoring any multiplier effect, peaceful applications account for 2.3 per cent and 1.9 per cent respectively of the Japanese and US GDP[1]. Further the International Atomic Energy Agency (IAEA) was established in 1957 and now has 134 Member states and a major program of nuclear technical cooperation which is contributing to the President's vision that the industrialised countries will dedicate "some of their strength to serve the needs rather than the fears of mankind."

2. A comment on the next fifty years (non-power civilian applications):

A vision for the future

A vision for the next 50 years is a world in which the fear of nuclear technology has disappeared from the minds of peoples and governments and its full potential to contribute to human well being and sustainable development will be realised.

Knowledge is fundamental to achieving this aim on a global basis. Over three thousand isotopes[2] are known (Figure 1[3]) and many can be used to obtain detailed

[1] These are 1995 figures reported by Professor Alan Waltar, Moderator Panel 3: Workshop II.
[2] For example: Table of the Nuclides http://www2.bnl.gov/CoN/index.html
[3] Airey PL and Howard CJ *Comment on a General Properties of Radionuclides* J Radioanal Nuc Chem Vol 257 No 1.

information on medical, industrial, agricultural and ecological systems. Basic knowledge from the atom is enhanced by modern numerical computation. Nuclear Medicine is the outstanding example. The versatility of radiopharmaceuticals coupled with the on-going advances in visualisation underpins diagnostic nuclear medicine, which benefits most people in developed countries and increasing numbers in the developing world. The impact of nuclear medicine, both now and in the future was discussed in this Seminar by Dr Y Sasaki (NIRS Japan, and Dr Hsu UCSF (US).

Eisenhower's concern for the "development of all mankind" is still a central issue 50 years on. However, the concern has now focussed on the sustainability of development. As with nuclear medicine, the diagnostic power of the atom has been augmented by a revolution in numerical computation to vastly enhance knowledge under-pinning strategies for sustainable development.

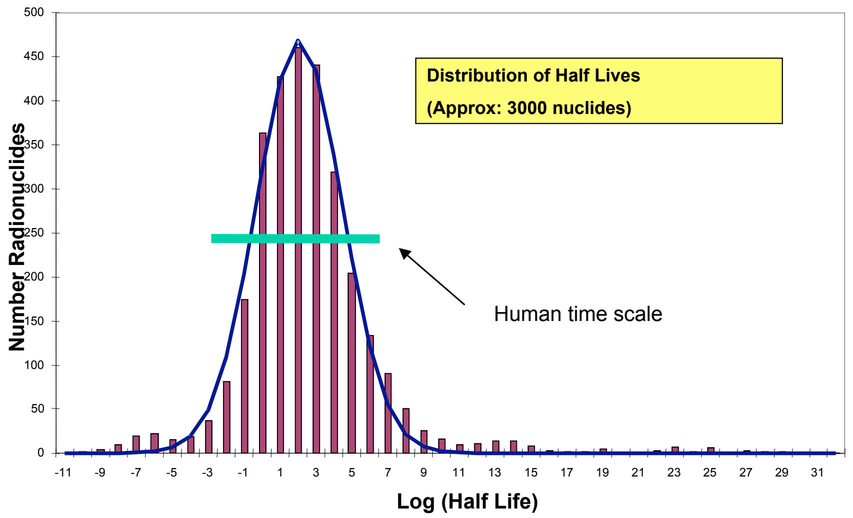

Figure 1: Half life distribution of isotopes listed in the Table of the Nuclides (footnote 3).

In this statement, the future trends will be analysed in terms of sustainable development with examples from industry and the environment. The following trends are foreseen over the next 50 years:

a) on-going advances in computation and visualisation;
b) increasing emphasis on minimising the wastage of material and energy through process optimisation;
c) the widespread availability of separated isotopes at a price which will permit new applications of these specialised materials;

INDUSTRIAL APPLICATIONS (I)

Drivers: waste minimisation, energy reduction and hence increased profitability through *process optimisation*

Future trend (I): **Enhanced data processing and visualisation**

•*Case study* : On-line industrial tomography

•*Current status* Developed for medical applications, tomographs applied to a very wide range of samples: from cell structure of wood to complex components and large motors etc

•*New example* Glass log project (Monash U)

•*Vision* The tomographing of each log to visualise veneers and optimise saw milling strategy for valuable rainforest logs

Comment: Generally speaking, advances in industrial applications arise from advances in medical and other supporting technologies

Figure 2: On-line industrial tomography; an outcome of enhanced data processing and visualisation.

d) increasing use of environmental isotopes as a tool for evaluation and refinement of global climate change models;
e) the widespread diffusion of nuclear technology to industrialising countries as a consequence of their increasing development status.

Specific examples of these trends are given in the boxes inserted in the text.

Applications of nuclear techniques to industry:

The goal of modern industrial processing is to generate quality products with a minimum wastage of energy and material, and hence a minimum impact on the environment[4]. Nuclear techniques have been applied to industrial problems for more than 50 years[5][6]. The very wide scope of applications are illustrated in Annexes 1 to 3. The data in Table 1 illustrates the relative frequency of commercial applications in Australia over the decade 1989 to 1999.

INDUSTRIAL APPLICATIONS (II)

Drivers: waste minimisation, energy reduction and hence increased profitability through *process optimisation*

Future trend (II): **process optimisation through increasingly sophisticated numerical modellling**

•*Impact* Where process modelling available, the need for diagnostic tests using tracers will be reduced

• *Challenges and opportunities*

•Investigations of processes too complex for effective modelling (eg FCCUs; minerals processing)

•Development of critical 'on-line' instrumentation (eg installed density gauges for three phase separator control in refineries)

Comment: Radiotracers will be increasing used for the evaluation of numerical models used in process control and environmental studies (including pollution studies and sand/sediment movement).

Figure 3: Optimisation of complex processes using numerical models validated using nucleonic and other techniques.

A powerful knowledge-based approach to achieving process optimisation involves systems modelling augmented by on-line nucleonic data. The techniques are very widely used in the refining, minerals processing, iron and steel and chemical industries.

Nuclear techniques contribute data not otherwise available for calibrating models and providing crucial information on processes which are so complex that they cannot be adequately modelled.

The next 50 years will witness major strides towards clean production and hence sustainable development that would not be possible without radioisotopes and radiation.

[4] Lowenthal GC and Airey PL.(2001) *Practical Applications of Radioactivity and Nuclear Radiations* Chap 7 'Industrial Applications of Radioisotopes and Radiation' pp 181 – 231.
[5] Charlton J.S. (Ed.) (1986) *Radioisotope Techniques for Problem Solving in Industrial Process Plants*. Leonard Hill, Glasgow, UK.
[6] IAEA (1990), *Guidebook on Radioisotope Tracers in Industry*, Technical Report Series No.316, International Atomic Energy Agency, POB 100, A-1400, Vienna, Austria.

Commercial organisations can now supply separated isotopes from most of the elements of the periodic table. This is likely to underpin emerging opportunities for product development over the coming decades.

INDUSTRIAL APPLICATIONS (III)

Driver: Emerging opportunities for manufacturing

Future trend (III): **Economic availability of separated isotopes** (in addition to uranium)

Examples: Si isotopes for chip manufacture;

Zn-64 depleted corrosion inhibitor in NPPs

Targets for source production

Ni-58 for neutron beam lines

Vision: Full range of isotopes for product development

Figure 4: Widespread availability of separated isotopes will underpin emerging opportunities in product development over the coming decades.

Application of nuclear techniques to the environment:

Spectacular advances in numerical computation and visualisation are also underpinning new insights into the behaviour of complex environmental systems. Examples of the applications of isotopes to environmental problems are listed in Annex 4 and discussed in numerous publications.

As an example, General Circulation Models are being developed to predict the impact of development on climate change. The incorporation of environmental isotope data into these and other environmental models will lead to a more robust basis for prediction. In the next 50 years, these enhanced predictions will contribute to human well being by underpinning strategies for the sustainable development of resources such as fresh water and fertile soil.

Table 1: INDUSTRIAL APPLICATIONS OF RADIOISOTOPES IN AUSTRALIA, 1989-1999 (J S Charlton, Johnson Matthey)

CATEGORY	APPLICATION	PER CENT
	Measurement of Density Profiles of Distillation Columns	19.3
	Detection of Depos	
	–	

The benefits of nuclear technology are widely recognised and have led to its global diffusion. This has been made possible by a generation of experts who have been motivated to share the benefits of the peaceful applications of nuclear technology as widely as possible.

SUSTAINABLE DEVELOPMENT(I)

Driver: the well being of future generations

Future trend: **Incorporation of environmental isotopes in the predictive modelling of climate change**

- *Case study:* Sustainability of groundwater resources in arid and semi arid regions under climate change;
- *Status:* Data from IAEA global "isotopes in precipitation" database incorporated in General Circulation Models (GCMs) and applied to NH precipitation and to the Amazon;
- Groundwater sustainability- a balance between effective recharge (climate dependent) and exploitation rate (regulatory issue)

Vision:

- Long term prediction of the effective recharge to groundwater through GCM modelling of climate parameters; and thereby
- contribute to the vision of *World Summit* Johannesburg 2002

Figure 5: The incorporation of environmental isotopes into Global Circulation Models will enhance the confidence with which the models can predict climate change.

The IAEA coordinates an extensive program of nuclear technical cooperation to developing countries. The Example cited here is Bangladesh. The IAEA supports projects and activities for which there is a demonstrated Government. Currently support is being provided for the management of thyroid disorders, for addressing the arsenic in groundwater catastrophe and for the manufacture of technetium generators for medical purposes.

The implementation of such activities in many countries over a number of decades has catalysed the diffusion of nuclear technologies into developing countries.

CONCLUDING COMMENT:

The essence of sustainable development is an assurance that the generation, which benefits from the nuclear applications, does not leave an unacceptable legacy for their sons and daughters. A vision for the next 50 years involves an inter-generational 'contract', or policy framework negotiated in good faith on behalf of those who cannot yet speak for themselves. This framework will include arrangements for radioactive waste. Where possible, short lived radioisotopes will be chosen so that the natural decay process will protect the future.

Ultimately the question of the impact of nuclear technology on human development needs to be addressed. A useful start is the United Nations Development

Programme's comment that human development[7] is "about creating an environment in which people can develop their full potential and lead productive, creative lives in accord with their needs and interests." President Eisenhower's vision for benefit of the atom to civil society is ultimately realised through its contribution to such ideals and to the more specific challenges of the 'millennium development goals'.

SUSTAINABLE DEVELOPMENT(II)

Driver: the well being of future generations

Future trend: improving development status of industrialising countries

Case studies: IAEA program of technical cooperation eg within Bangladesh

Status: The current program is directed towards

•the management of thyroid disorders

•addressing the arsenic in groundwater catastrophe through isotope hydrology approach;

•supporting appropriate nuclear technology (development of Tc-99m generator production)

Comment: IAEA only supports programs for which there is a demonstrated government commitment.

Figure 6: Nuclear technology is diffusing widely into industrialising countries and contributing to the enhancement of their development status.

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[7] http://hdr.undp.org/hd/default.cfm

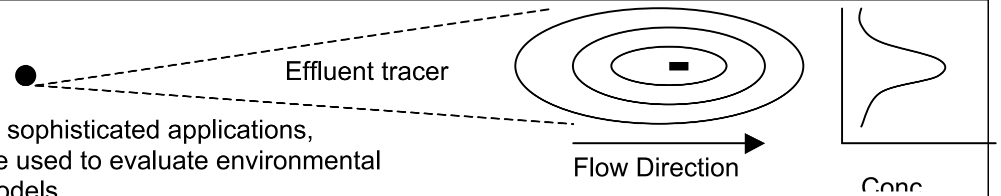
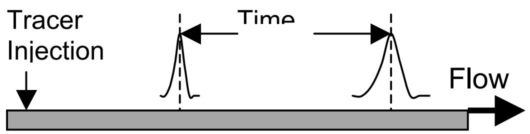
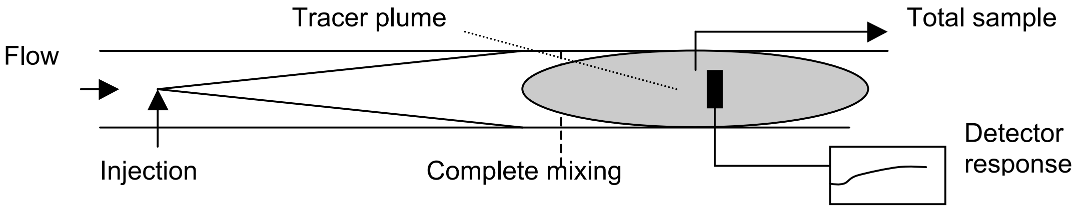
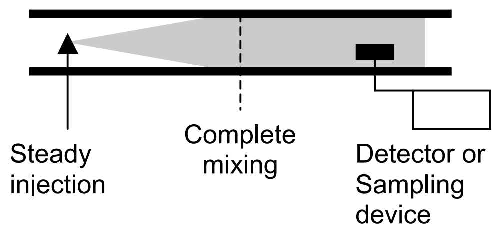
Annex 1: **Industrial Applications of Nucleonic Gauges**

RADIATION	PROPERTY	APPLICATION	EXAMPLE
Gamma rays	Transmission	Level gauges	To monitor and control the levels of liquids and solids in chemical reactors, tanks and hoppers
		Density gauges	To measure the density of materials in industrial plants and in minerals processing streams as well as sediments in rivers and estuaries.
		Column scanning	To diagnose reasons for poor performance of industrial columns during plant operation
		Industrial radiography and tomography systems	To visualise the internal structure of, say, machine components and of heterogeneous materials in 2 dimensions (radiography) or 3 dimensions (tomography)
	Back-scatter	Level gauges	To determine the levels of liquids in tanks
		Gamma-gamma bore-hole logging	Measure the bulk density of strata, and thence eg a) to monitor the location of the water table in aquifers; and b) to monitor the oil/water interface in oil wells.
Beta particles	Transmission	Thickness measurements	Thickness control in paper manufacturing industry based on the attenuation of transmitted ^{85}Kr β particles. Associated measurement s (eg moisture) measured using microwave techniques.
Neutrons	Backscatter	Measure differences in the hydrogen content of materials	a. Monitoring liquid levels in tanks; b. Monitor moisture content of engineering materials c. Borehole logging (including neutron moisture meters)
	Neutron activation - prompt gamma emission	Borehole logging	Obtain data on the elemental composition of the surrounding strata, and hence information on the lithology, and groundwater salinity
		On-line analysis	Monitor the level of sulphur and the elemental composition of ash in coal on conveyor belts
Alpha particles	Ionisation	Smoke detectors	Monitor the enhanced ionisation current in the presence of smoke.

Annex 2: **Industrial Applications of radiotracers**

INDUSTRY SECTOR	INVESTIGATION	APPLICATIONS
Refining	Fluidised Catalytic Cracking Units (FCCU)	Velocities of vapour and the catalyst in the riser; separation efficiency of the catalyst and vapour
	Leakage and blockages in pipelines and chemical reactors	* Short circuiting through catalyst * leakage and blockage in sub-surface pipelines
	Fluid flow rates	* Meter calibration – liquid and gas flow * Mass balance studies
Oil and Gas field	Effectiveness of enhanced oil re-covery strategies based on injection of water (with additives) or gas into the field at selected locations.	* used to identify, for example, short circuiting; * validation of mathematical models of the process
	Leakage between gas bearing strata in a production field	^{85}Kr or T (or ^{14}C) labelled light hydro-carbons injected at observation wells and migrate to pro-duction wells.
Chemical	Flow rate measure-ments for *in situ* meter calibration.	Point to point and tracer dilution methods widely used
	Mercury inventories	Tracer dilution using ^{203}Hg and/or ^{197}Hg
	Leakages and blockages	
Minerals	Process optimisation	Frequently involve residence time (RTD) studies.
	Hot processing of ores and concen-trates	Wide range of tracer techniques to study the processes in shaft furnaces and roasting furnaces
	Electrorefining	Measuring the efficiency of the electrolytic prod-uction of aluminium.
Iron and steel	Blast furnaces	Refractory lining wear. Sealed ^{60}Co sources into selected refactory bricks during lining; as bricks erode pellet also erodes and radiation level falls.
	Blast furnaces	Simultaneous RTD studies on the iron and slag
Cement	Pre-mixing silos	Efficiency of mixing of the four component stock in silos.
	Rotary kiln	Residence time studies
Mechanical engineering	Wear tests	Activation of pistons or cylinders and monitoring of activity of eroded material in test rig

Annex 3 **Application of tracer techniques to fluid dynamics**

Measurement	Technique	Application	Comment
1. Dilution factors	Samples are taken downstream of the injection point and the tracer concentrations expressed as fractions of those at a reference location.	*Environmental Eng:* Assessment of the effectiveness of engineering structures (eg sewage outfalls) in diluting effluent into, say, waters.	
2. Dispersion	Tracer techniques can be used to measure the capacity of receiving waters to dilute and disperse effluent. If the tracer is released as a point source, say from an ocean outfall, the tracer concentration profiles frequently approximate Gaussian curves. An analysis of these curves yields dispersion coefficients in the longitudinal, transverse and depth directions.	In the most sophisticated applications, methods are used to evaluate environmental transport models.	
3 Flow rates 3.1 Pulse velocity	An isotope pulse is injected into, say a pipeline, a channel or a river and the flow rate measured by noting the time for the passage of the pulse between two points. To calculate the volume flow, the average cross-section must be known.	Because of its simplicity, the method is widely used for the measurement of flows in industry and the environment. For the most accurate measurements, an analysis of the pulse shape is necessary under conditions of complete mixing.	
3.2 Tracer dilution techniques	A tracer is injected into a pipeline, channel or river, either at a steady rate, or as a pulse. After complete mixing has been achieved, the dispersing plume is monitored. Measurement of the cross sectional areas are not necessary to calculate volume flows.		
3.2.1 Steady state injection	The tracer is injected at a steady rate for a period necessary to establish a steady concentration of tracer at the measurement point (see Figure).	Although the most accurate method, it is not widely used because considerably more tracer is required than with the pulse methods.	
3.2.2 Pulse injection	The tracer is injected as an instantaneous pulse and monitored after achievement of complete mixing.	ß Since volume flow rates do not require cross-sectional area measurements, they are ideally suited for channels etc with rough profiles. ß Using the total sample method, the mas flow of gas may be measured knowing the density of gas under ambient conditions after sampling.	
3.2.2.1 Total sample method	A sample is pumped from a given point at a constant rate for a measured time during the whole pulse.		
3.2.2.2 Total count method	The integrated net count rate from a calibrated detector at a fixed location is measured.		

Annex 4 Environmental radioisotopes*.

Isotope	Source	Half life	Application	Comments
H-3 (tritium)	Atmos. testing; Cosmogenic	12.25 a	*Groundwater recharge *Oceanographic mixing	Environmental tritium dominated by atmospheric testing source; hence tritium in water implies that a component of the water from 'post nuclear' ie post 1950 precipitation. Environmental tritium is used to identify groundwater recharge areas and to study oceanographic surface mixing processes .
Be-7	Cosmogenic	53 d	Sediment accumulation and redist-ribution over the previous half year	The presence of Be-7 in a sediment core indicate that the material has been at the surface over the past six months. Be-7 is correlated with ^{137}Cs in sediment cores which provides information on the rate of accumulation of sediment in post nuclear times ie over the past 40 years.
C-14	Atmospheric testing	5730 a		In post nuclear times, atmospheric testing is the major source of C-14. It therefore exhibits a typical 'bomb' pulse which has been used for example ß to study the uptake of CO_2 by the oceans; ß to investigate mixing processes in the upper layers of the oceans in post nuclear times;and ß to provide independent evidence of the source of carbon (modern vegetation or mineral) in commercial products should it be contested.
	Cosmogenic,		Pre-history; Evolution of coastal and other ecological systems in recent geological time; Global climate change studies.	C-14 is used for dating carbon containing materials up to 50,000 y. The technique has been widely used for ß dating artefacts, bones and charcoal and thereby making a major contribution to an understanding of pre-history and the evolution of ecological systems; ß studying groundwater flow patterns; ß investigating coastal processes through, for instance, the dating of marine corals, of shell grit in dunes and of sediments in estuaries and lakes; ß better understanding global oceanographic circulation patterns; and ß dating of tree rings, ice cores and corals as a contribution to global climate change studies.
Cℓ-36	Atmos testing	310,000 a	Salinity, ground-water quality	The Cℓ-36 bomb pulse is used to chloride migration ie salinity processes in the unsaturated zone and in the modern groundwater.
	Cosmogenic		Dating of old groundwater	Cℓ-36 is used to date groundwater up to 1M years. More generally it is used to study aspects of the chloride cycle ie the evolution of groundwater quality.
Cs-137	Atmos. testing	30.1	Sedimentation, soil erosion	Cs-137 is used to measure the rate of sedimentation and erosion in post nuclear times.
Pb-210	U series	22.2 a	Sediment dating over the past 100y	The ^{210}Pb method has been extensively applied to the dating of sediments in lakes and estuaries over the past 100 years. The sediment is cored and individual sections assayed for ^{210}Pb. There are two components of ^{210}Pb, the unsupported and the supported. The unsupported lead, which is used in measuring the accumulation rates, is adsorbed on the surface from the decay of the ^{222}Rn dissolved in the associated water. The supported ^{210}Pb is derived from the decay of the ^{238}U within the sediment minerals. Experimentally, the supported lead is calculated from the measured uranium levels, and is subtracted from the total to obtain the 'unsupported' component.

* Adapted from **Lowenthal and Airey (2001)** Table 9.2 page 273 to 277